US009247994B2

(12) **United States Patent**
Reid, Jr.

(10) **Patent No.: US 9,247,994 B2**
(45) **Date of Patent: Feb. 2, 2016**

(54) **ABLATION SYSTEMS, PROBES, AND METHODS FOR REDUCING RADIATION FROM AN ABLATION PROBE INTO THE ENVIRONMENT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/811,192**

(22) Filed: **Jul. 28, 2015**

(65) **Prior Publication Data**

US 2015/0327929 A1 Nov. 19, 2015

Related U.S. Application Data

(62) Division of application No. 13/343,798, filed on Jan. 5, 2012, now Pat. No. 9,113,930.

(51) **Int. Cl.**
A61B 18/18 (2006.01)
A61B 18/00 (2006.01)

(52) **U.S. Cl.**
CPC ... ***A61B 18/1815*** (2013.01); *A61B 2018/00023* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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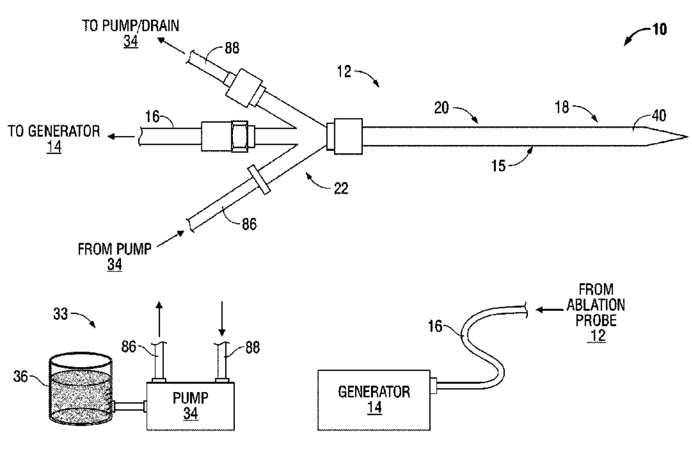
(57) **ABSTRACT**

The ablation systems, ablation probes, and corresponding methods according to the present disclosure reduce or eliminate energy radiating from an ablation probe into the environment. Some ablation probes include a retractable sheath that shields at least the radiating portion of the ablation probe. The retractable sheath and/or the ablation probe may include conduits through which a fluid may flow to shield the radiating portion and to drive the retractable sheath to an extended state. Other ablation probes include apertures defined in the probe walls through which the fluid can flow to expand a balloon surrounding the radiating portion. Yet other ablation probes include a thermal indicator to indicate the temperature of the ablation probe to a user. The ablation systems include fluid circuits and associated mechanical controls for varying the contents and/or flow rate of the fluid provided to the radiating portion of the ablation probe.

19 Claims, 11 Drawing Sheets



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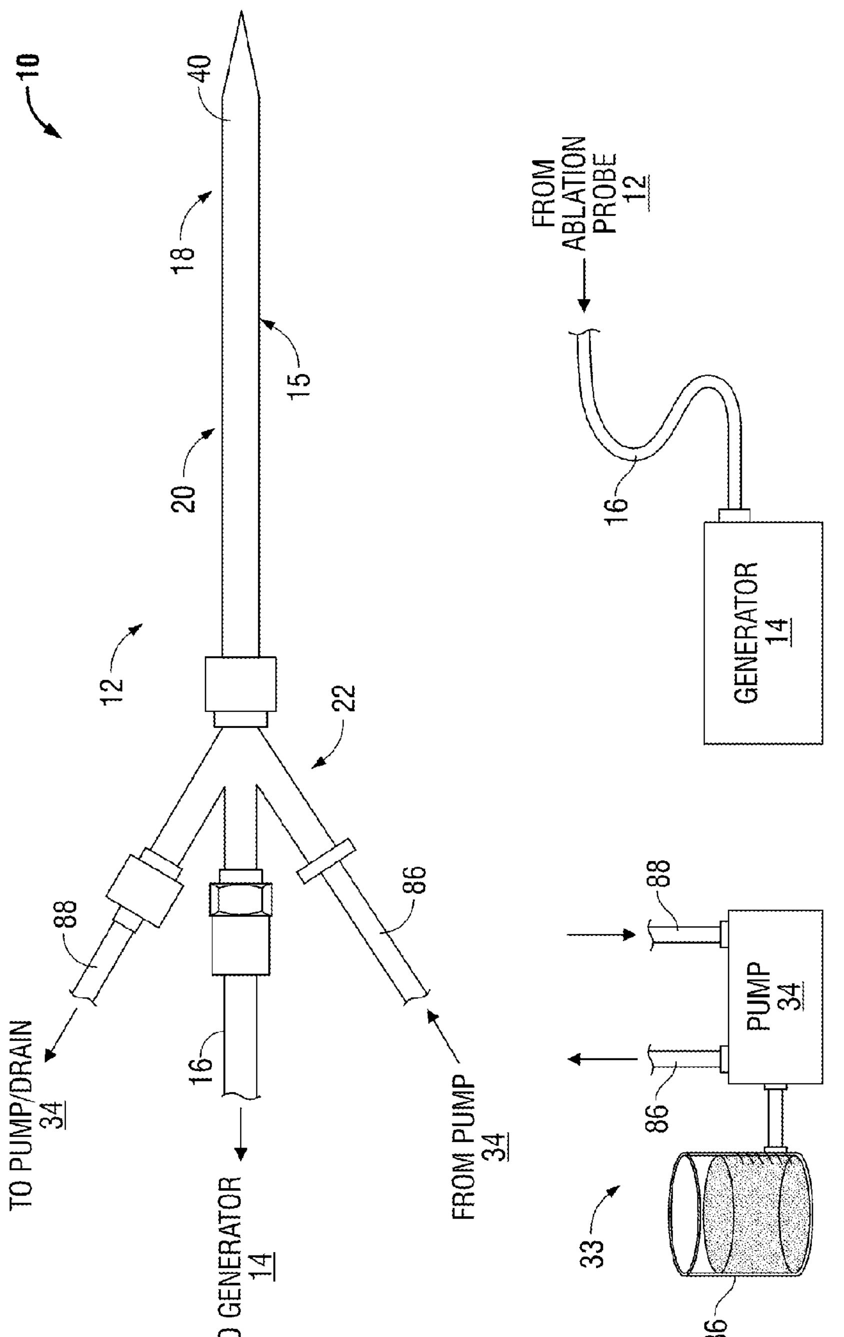

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ABLATION
PROBE
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GENERATOR
14
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PUMP
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FIG. 1

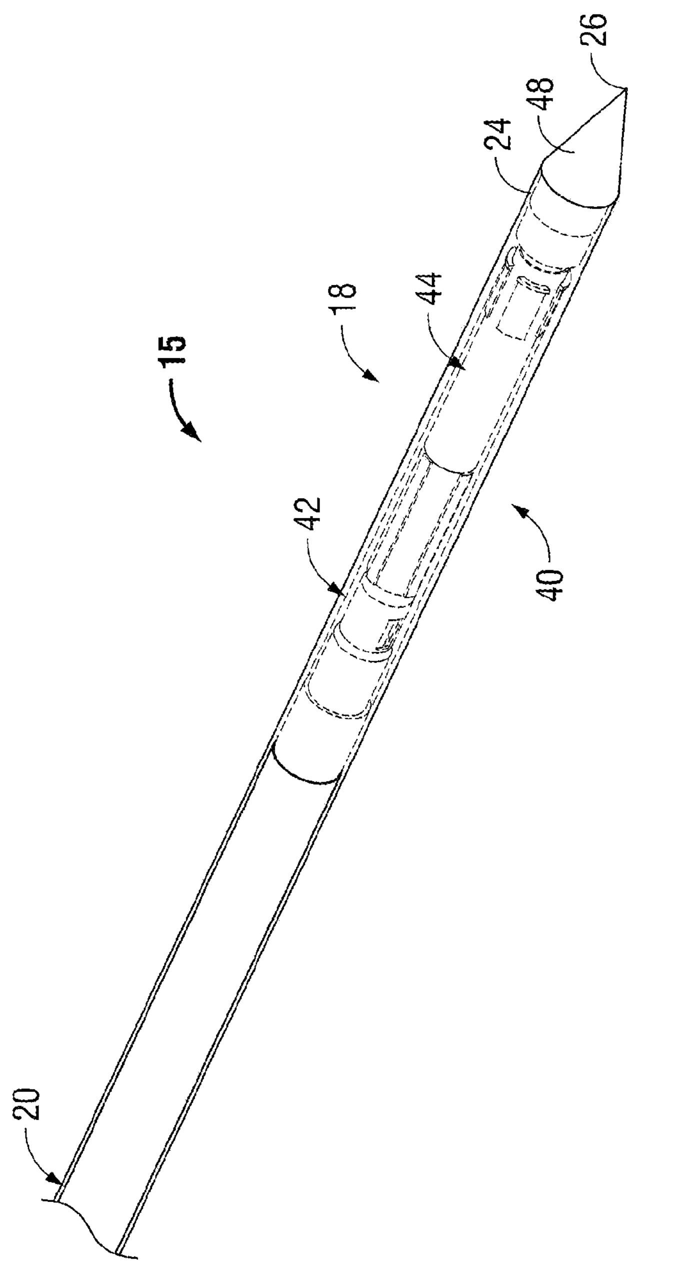

FIG. 2A

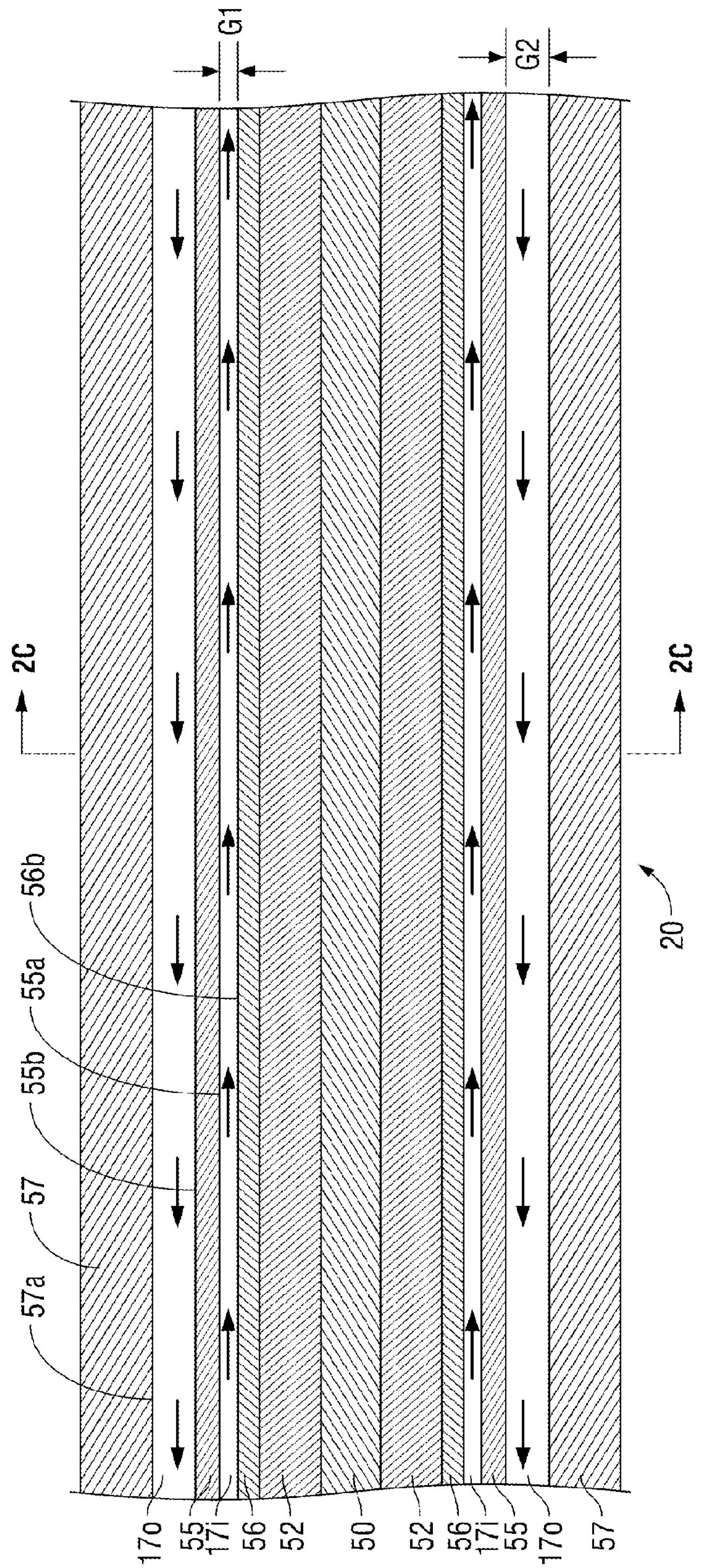
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FIG. 2B

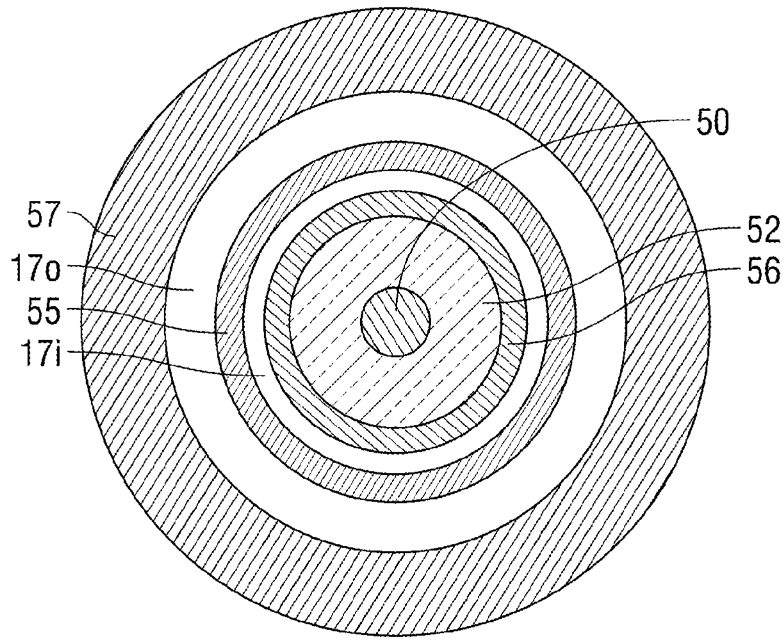

FIG. 2C

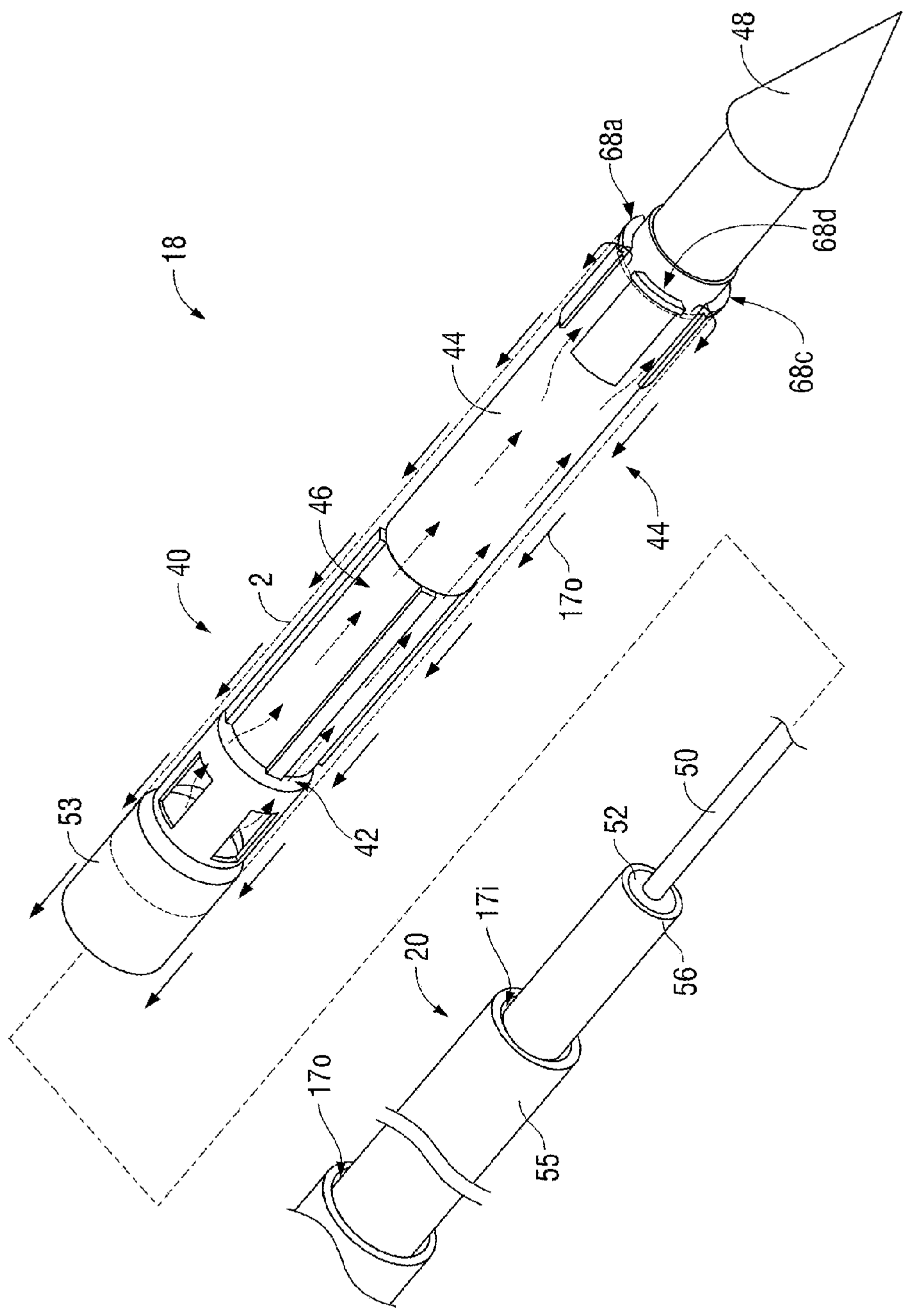

FIG. 2D

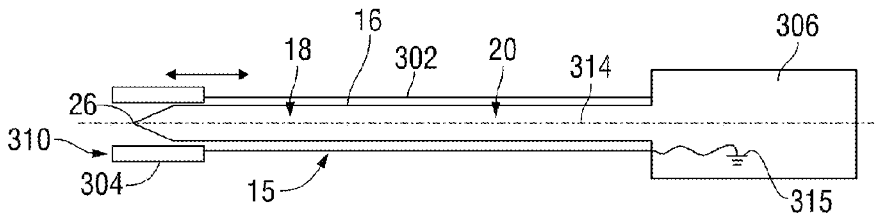

FIG. 3

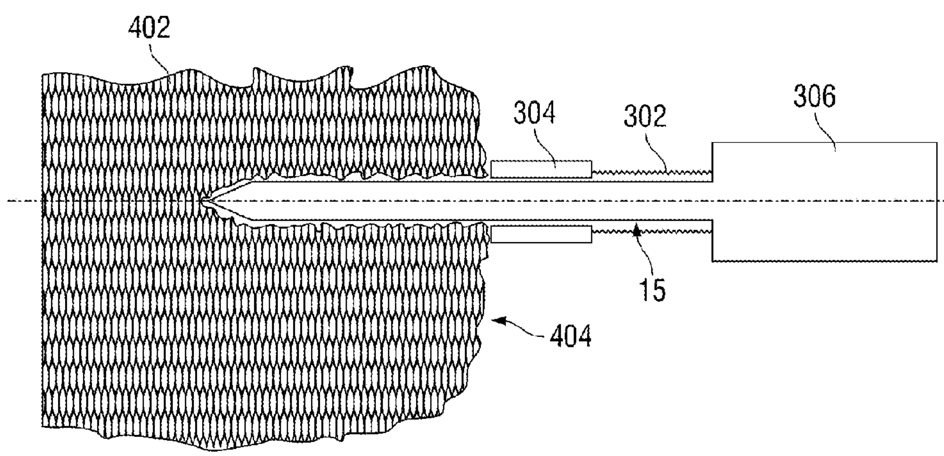

FIG. 4

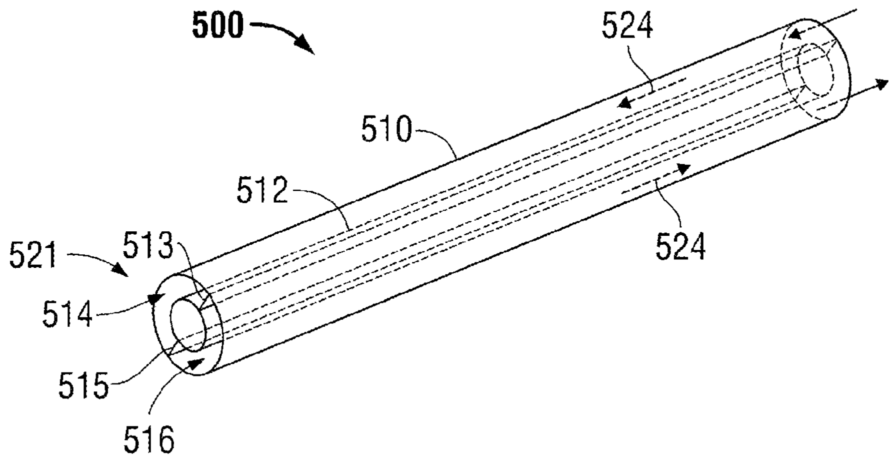
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FIG. 5A

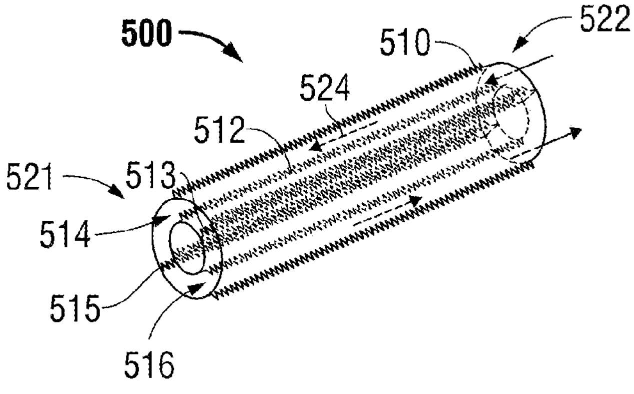
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FIG. 5B

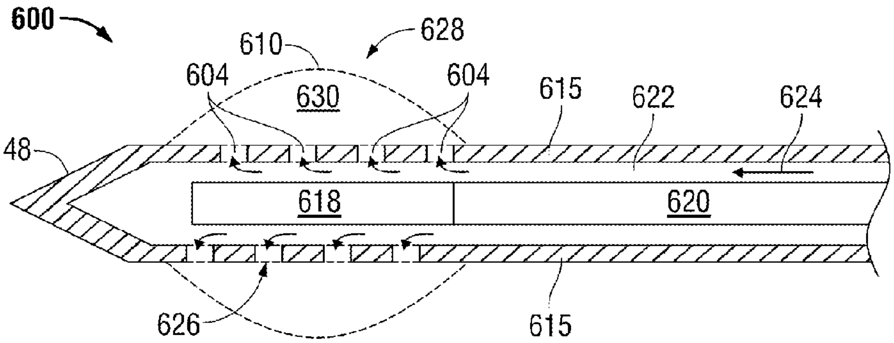


FIG. 6

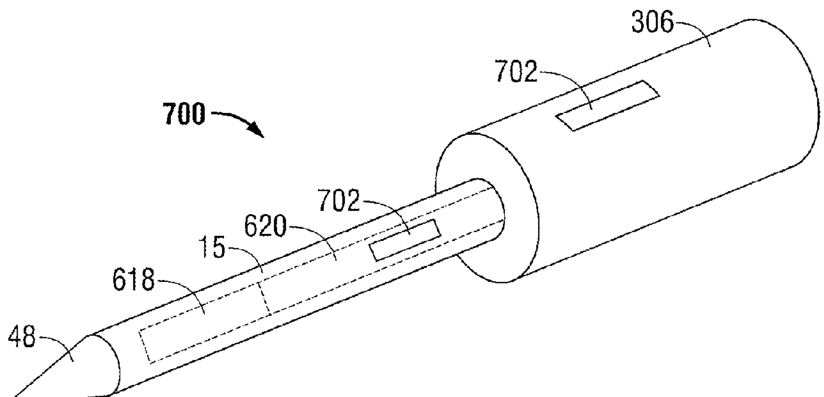


FIG. 7A

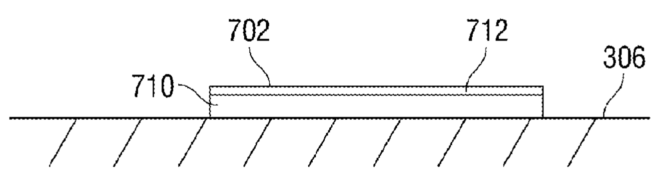
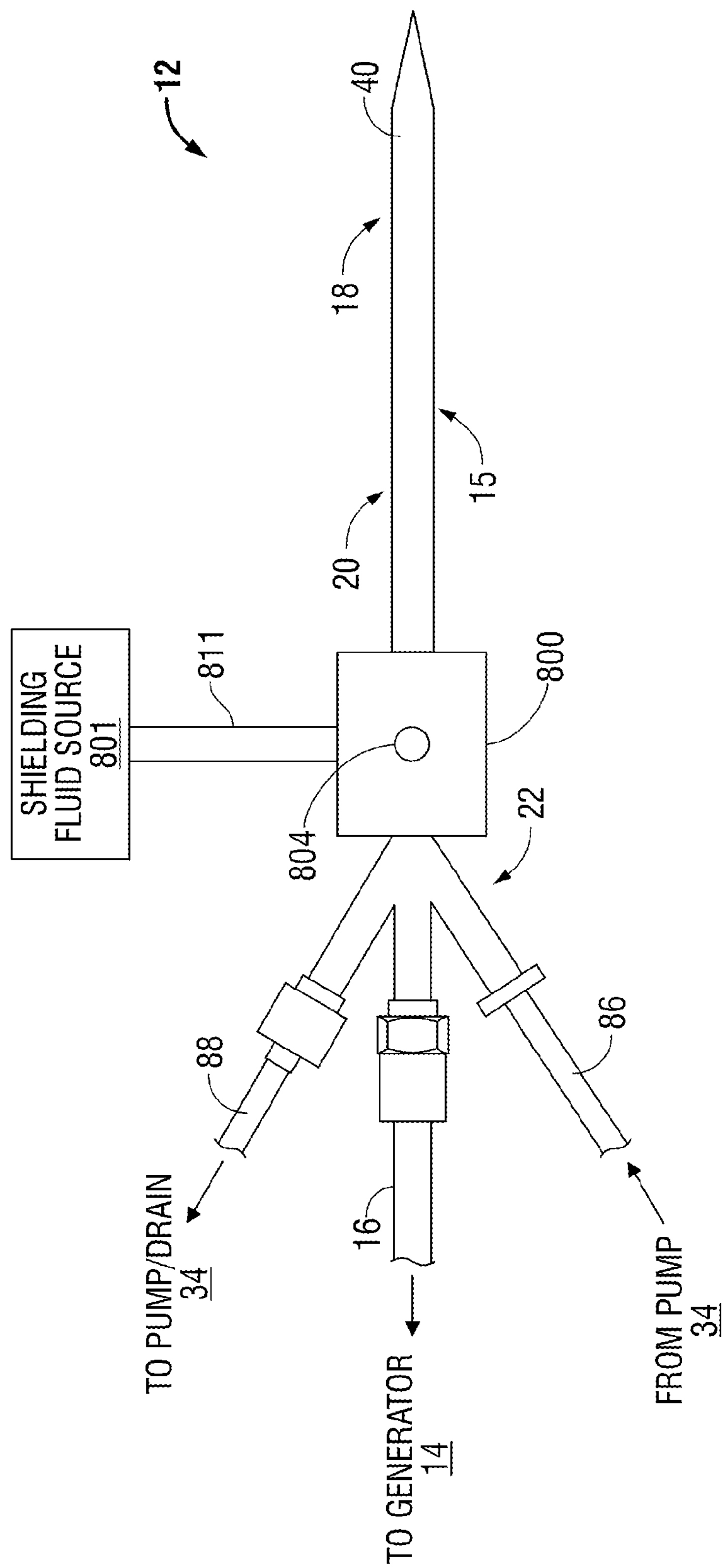


FIG. 7B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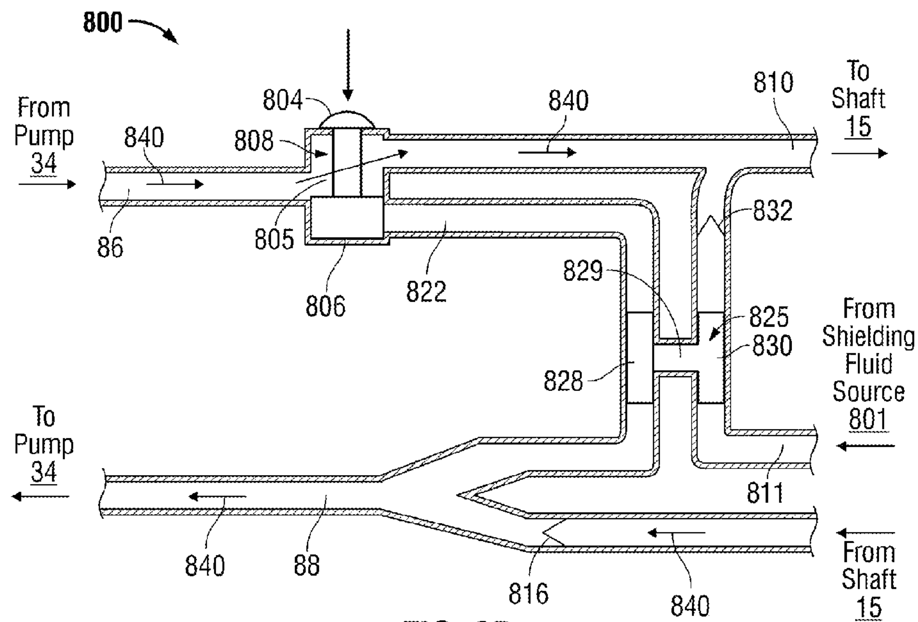
FROM PUMP 34

FIG. 8A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828
From
Shielding
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From
Shaft
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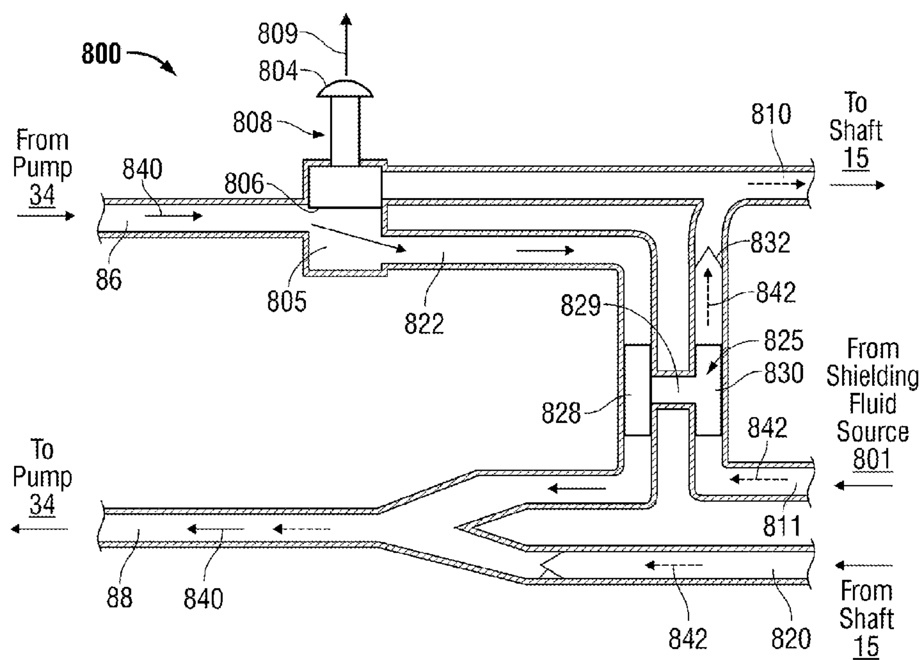
FIG. 8B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830
828
842
From
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Fluid
Source
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To
Pump
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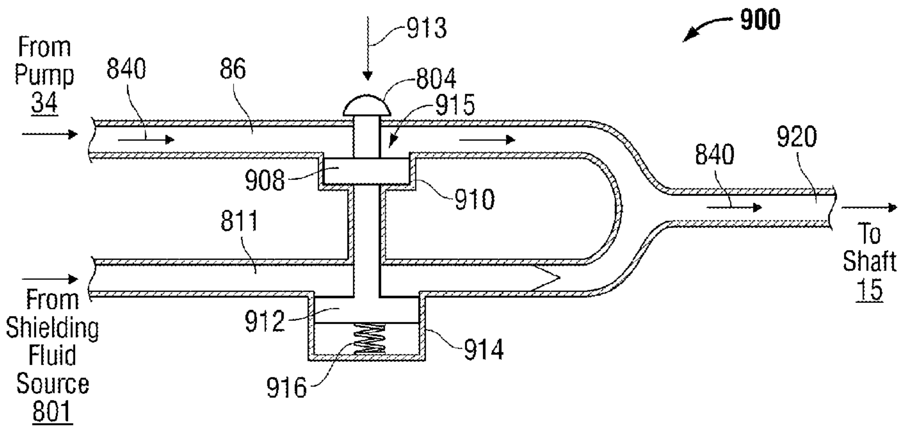
842
820
From
Shaft
15

FIG. 8C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914
916

FIG. 9A

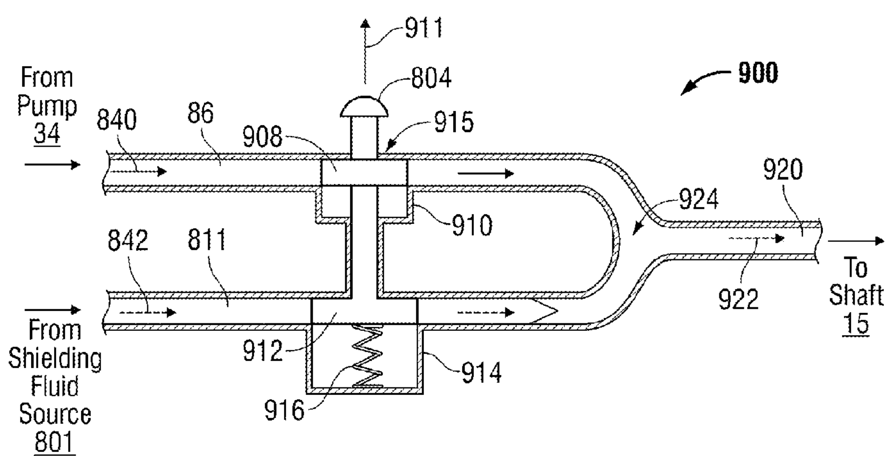
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FIG. 9B

ABLATION SYSTEMS, PROBES, AND METHODS FOR REDUCING RADIATION FROM AN ABLATION PROBE INTO THE ENVIRONMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. patent application Ser. No. 13/343,798 filed on Jan. 5, 2012, the entire contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

The present disclosure generally relates to ablation systems. More particularly, the present disclosure is directed to ablation systems, probes, and methods for reducing or eliminating energy radiating from an ablation probe into a surgical environment.

2. Background of Related Art

In the treatment of diseases such as cancer, certain types of cancer cells have been found to denature at elevated temperatures (which are slightly lower than temperatures normally injurious to healthy cells.) These types of treatments, known generally as hyperthermia therapy, typically utilize electromagnetic radiation to heat diseased cells to temperatures above 41° C., while maintaining adjacent healthy cells at lower temperatures where irreversible cell destruction will not occur. Other procedures using electromagnetic radiation to heat tissue include ablation and coagulation. These procedures are typically done to denature or kill the targeted tissue.

Many medical procedures and devices that use electromagnetic radiation are known in the art. Some of these procedures and devices are used to treat tissue and organs, such as the prostate, heart, liver, lung, kidney, and breast. These medical procedures and devices can be broken down into two general categories: non-invasive and invasive.

Some non-invasive procedures involve treating tissue (e.g., a tumor) underlying the skin with microwave energy. The microwave energy non-invasively penetrates the skin to reach the underlying tissue. However, this non-invasive procedure may result in unwanted heating of healthy tissue. Thus, non-invasive procedures that use microwave energy require precise temperature control.

Some invasive procedures have been developed in which a microwave antenna probe is either inserted directly into a point of treatment via a normal body orifice or inserted percutaneously. These invasive procedures can provide better temperature control of the tissue being treated. Because of the small difference between the temperature required for denaturing malignant cells and the temperature injurious to healthy cells, a known heating pattern and predictable temperature control is important so that heating is confined to the tissue being treated. For instance, hyperthermia treatment at the threshold temperature of about 41.5° C. generally has little effect on most malignant growth of cells. However, at slightly elevated temperatures above the approximate range of 43° C. to 45° C., thermal damage to most types of normal cells is routinely observed. Accordingly, great care must be taken not to exceed these temperatures in healthy tissue.

To prevent damage to healthy tissue, the non-radiating portion of the ablation probe is cooled with a cooling solution having dielectric properties that are matched to the dielectric properties of the target tissue. When the ablation probe is removed from tissue, however, the probe still has the ability to efficiently radiate microwave energy because of the dielectric

buffering provided by the cooling solution. Therefore, if the generator is still powering the probe after it is removed from tissue, individuals near the probe may be unnecessarily exposed to microwave energy.

SUMMARY

The systems and methods according to the present disclosure reduce or eliminate radiation from an ablation probe into the environment and require few or no changes to the generator. Thus, the ablation probes according to the present disclosure can be used with existing generators.

In one aspect, the present disclosure features an ablation system. The ablation system includes a probe having a proximal portion and a distal portion. The distal portion has a radiating portion configured to deliver energy to tissue. The ablation system also includes a fluid circuit module. The fluid circuit module includes a common fluid conduit, a first fluid supply conduit, and a second fluid supply conduit. The common fluid conduit is configured to supply fluid to at least a portion of the radiating portion. The first fluid supply conduit carries a first fluid to the common fluid conduit. The first fluid facilitates the transmission of energy from the radiating portion to tissue. The second fluid supply conduit supplies a second fluid to the common fluid conduit. The second fluid prevents transmission of at least a portion of the energy to tissue or a surrounding environment.

In some embodiments, the fluid circuit module further includes a fluid return conduit configured to carry the first fluid, a mixture of the first fluid and the second fluid, or the second fluid away from the radiating portion. In some embodiments, the first fluid supply conduit includes a first recessed portion and the second fluid supply conduit includes a second recessed portion and the ablation system further includes a fluid pump, an impeller, and a manual control.

The fluid pump fits within the second recessed portion and moves from a first position within the second recessed portion to a second position outside of the second recessed portion. The fluid pump pumps the second fluid through the second fluid supply conduit when the fluid pump is positioned outside of the second recessed portion. The impeller is operatively coupled to the fluid pump to drive the fluid pump. The impeller fits within the first recessed portion and is moveable from a first position within the first recessed portion to a second position outside of the first recessed portion. The impeller is driven by the first fluid flowing through the first fluid supply conduit when the impeller is positioned outside of the first recessed portion. The manual control is operatively coupled to the impeller and the fluid pump. The manual control moves the impeller and the fluid pump between respective first positions and respective second positions.

In other embodiments, the fluid circuit module further includes a fluid return conduit fluidly coupled to the common fluid conduit, a bypass fluid conduit fluidly coupled between the first fluid supply conduit and the fluid return conduit, a fluid pump disposed within the second fluid supply conduit, an impeller disposed within the bypass fluid conduit and operatively coupled to the fluid pump to drive the fluid pump, and a bypass valve assembly fluidly coupled to the first fluid supply conduit and the bypass fluid conduit. In this configuration, the fluid pump pumps the second fluid through the second fluid supply conduit, the impeller is driven by the first fluid flowing through the bypass fluid conduit, and the bypass valve assembly diverts the first fluid flowing in the first fluid supply conduit to the bypass fluid conduit when actuated.

In some embodiments, the second fluid is a liquid solution containing particles that absorb electromagnetic energy. In other embodiments, the second fluid is either air or a gas containing nitrogen.

In some embodiments, the ablation system further includes a check valve disposed within the second fluid supply conduit. This check valve prevents the first fluid from flowing into the second fluid supply conduit. In some embodiments, the ablation system includes a check valve disposed within the fluid return conduit. This check valve prevents fluid from flowing distally.

In yet other embodiments, the probe of the ablation system includes a hollow elongated shaft having a plurality of apertures formed in a distal portion of the shaft, a balloon attached to an outer surface of the hollow elongated shaft to enclose the plurality of apertures, a tip enclosing a distal end of the hollow elongated shaft, and an electrical conductor disposed within the hollow elongated shaft. The balloon expands when the first fluid, the second fluid, or a mixture of the first fluid and the second fluid flows through the plurality of apertures to form a fluid chamber between the balloon and the outer surface of the hollow elongated shaft. The electrical conductor includes a radiating portion at the distal end of the electrical conductor. The radiating portion is aligned with the balloon. Also, an outer surface of the electrical conductor and an inner surface of the hollow elongated shaft form a fluid conduit in fluid communication with the plurality of apertures.

In some embodiments, the probe further includes a retractable sheath surrounding at least the radiating portion. The retractable sheath prevents at least a portion of the energy from radiating outside of the retractable sheath and retracts as the hollow elongated shaft is inserted into tissue.

In another aspect, the present disclosure features a method of operating an ablation probe. The method includes supplying a first fluid to a radiating portion of the ablation probe when the radiating portion is inserted in tissue, and supplying a second fluid to the radiating portion of the ablation probe when the radiating portion is removed from tissue to shield the radiating portion of the ablation probe from the surrounding surgical environment.

In some embodiments, supplying the second fluid occurs while supplying the first fluid to the radiating portion. Supplying the second fluid may include pumping the second fluid using a flow of the first fluid. The method may further include terminating the step of supplying a first fluid to the radiating portion at the onset of the step of supplying the second fluid.

In some embodiments, supplying the first fluid may include moving a fluid valve assembly from a first position to a second position. Also, supplying the second fluid may include moving the fluid valve assembly from the second position to the first position.

In yet another aspect, the present disclosure features an ablation probe. The ablation probe includes a hollow elongated shaft having a plurality of apertures formed in a distal portion of the hollow elongated shaft, a balloon attached to an outer surface of the hollow elongated shaft to enclose the plurality of apertures, a tip enclosing a distal end of the hollow elongated shaft, and an electrical conductor disposed within the hollow elongated shaft. The balloon expands when pressurized fluid flows through the plurality of apertures to form a fluid chamber between the balloon and the outer surface of the hollow elongated shaft. The conductor includes a radiating portion at the distal end of the electrical conductor in alignment with the balloon. An outer surface of the electrical conductor and an inner surface of the hollow elongated shaft form a fluid conduit fluidly coupled to the plurality of apertures.

In the present disclosure, the term "proximal" refers to the portion of a structure that is closer to a user, while the term "distal" refers to the portion of the structure that is farther from the user.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present disclosure are described herein with reference to the drawings wherein:

FIG. **1** is a diagram of a microwave ablation system according to embodiments of the present disclosure;

FIG. **2**A is an perspective view of a distal portion of an ablation probe according to some embodiments of the present disclosure;

FIG. **2**B is a longitudinal, cross-sectional view of a feed line portion of the ablation probe of FIG. **2**A;

FIG. **2**C is a transverse, cross-sectional view of the feed line portion of the ablation probe of FIG. **2**A taken along the line **2**C-**2**C of FIG. **2**B.

FIG. **2**D is an internal perspective view of the distal portion of the ablation probe of FIG. **2**A illustrating the coaxial inflow and outflow channels.

FIG. **3** is a schematic, cross-sectional side view of an ablation probe having a retractable sheath according to some embodiments of the present disclosure;

FIG. **4** is a schematic, cross-sectional side view of the ablation probe of FIG. **3** in which the retractable sheath is in a retracted state;

FIG. **5**A is a schematic, perspective view of a retractable sheath according to other embodiments of the present disclosure;

FIG. **5**B is a schematic, perspective view of the retractable sheath of FIG. **5**A in a retracted state;

FIG. **6** is a schematic, cross-sectional side view of an ablation probe incorporating an expandable balloon according to some embodiments of the present disclosure;

FIG. **7**A is a schematic, perspective view of an ablation probe having a passive thermal sensor according to some embodiments of the present disclosure;

FIG. **7**B is a schematic, cross-sectional side view of the passive thermal sensor disposed on the ablation probe of FIG. **7**A;

FIG. **8**A is a diagram of an ablation probe incorporating a fluid circuit for feeding shielding fluid to the ablation probe;

FIGS. **8**B and **8**C are schematic diagrams of a fluid circuit for adjusting the properties of the shielding fluid fed to the ablation probe according to some embodiments of the present disclosure; and

FIGS. **9**A and **9**B are schematic diagrams of a fluid circuit for adjusting the properties of the fluid fed to the ablation probe according to other embodiments of the present disclosure.

DETAILED DESCRIPTION

Particular embodiments of the present disclosure are described below with reference to the accompanying drawings.

Generally, the present disclosure relates to systems and corresponding methods for reducing or eliminating energy that radiates from ablation probes into the environment. These systems and corresponding methods require few or no changes to the electrosurgical generator that supplies power to the ablation probe. The systems include various shielding mechanisms for shielding individuals from unnecessary energy radiating from the ablation probe when it is removed from tissue.

The ablation systems according to the present disclosure include a retractable sheath or shield that shields at least the radiating portion of the ablation probe to reduce or eliminate the radiation of energy (e.g., microwave energy) into the environment. The retractable sheath may include conduits through which a shielding fluid flows to shield the radiating portion of the ablation probe. The shielding fluid may also be used to drive the retractable sheath from a retracted state to an extended state. In some embodiments, the ablation probe includes apertures formed in the walls of the ablation probe near the radiating portion and a balloon surrounding the ablation probe to cover the apertures. In these embodiments, the shielding fluid flows through the apertures into the balloon to expand the balloon surrounding the radiating portion.

The ablation systems also include fluid circuits having mechanical controls that vary the contents and/or flow rate of the shielding fluid that cools the radiating portion. For example, when the user operates (e.g., applies force to) the mechanical controls (e.g., the user uses his/her finger to depress a button), the cooling solution flows to the radiating portion. When the user again operates (e.g., removes force from) the mechanical controls (e.g., the user removes his/her finger from the button or depresses the button again), the shielding fluid or a mixture of the cooling solution and the shielding fluid is supplied to the radiating portion. The cooling solution may include cooled water or a water-based solution. The shielding fluid may also include a mixture of water and small particles of dielectric material.

An ablation system according to embodiments of the present disclosure includes an ablation probe **12** having an antenna and/or an electrode that delivers energy to tissue. FIG. **1** illustrates an ablation system **10** including the ablation probe **12**, a microwave generator **14**, and a cooling fluid supply **33**. The ablation probe **12** is coupled to the microwave generator **14** via a flexible coaxial cable **16**. The ablation probe **12** is also fluidly coupled to the cooling fluid supply **33** via a fluid supply line or conduit **86** and a fluid return line or conduit **88**. Cooling fluid leaves the ablation probe **12** through the fluid return line **88**.

In a closed-loop cooling fluid system, the ablation probe **12** is fluidly coupled to the cooling fluid supply **33** via fluid return line **88** and cooling fluid is cycled through the cooling fluid supply **33**. In an open-loop cooling fluid system, the cooling fluid flows through the fluid return line **88** to a drain or other suitable disposable receptacle and new cooling fluid is supplied to the cooling fluid supply **33** from a cooling fluid reservoir **36** or other suitable source of cooling fluid.

The ablation probe **12** generally includes a connection hub **22** and a shaft **15**. The distal portion of the shaft **15** includes a radiating portion **18** and the proximal portion of the shaft **15** includes a feed line **20**. The connection hub **22** connects the microwave generator **14** and the cooling fluid supply **33** to the ablation probe **12**. The microwave signal is produced by the microwave generator **14**, transmitted through the flexible coaxial cable **16**, which connects to the connection hub **22**, and the connection hub **22** facilitates the transfer of the microwave signal to the feed line **20**. The connection hub **22** further facilitates the transfer of cooling fluid to and from the feed line **20**. Cooling fluid, provided from the fluid pump **34** of the cooling fluid supply **33**, is provided to the connection hub **22** through the fluid supply line **86**. The connection hub **22** transfers the cooling fluid from the fluid supply line **86** to the cooling fluid supply lumen (not explicitly shown) of the feed line **20**.

The cooling fluid, after being circulated through the feed line **20** and radiating portion **18** of the ablation probe **12**, is returned to the connection hub **22** through the return lumen (not explicitly shown) of the feed line **20**. Connection hub **22** facilitates the transfer of the cooling fluid from the return lumen (not explicitly shown) to the fluid return line **88**.

In one embodiment, the microwave ablation system **10** includes a closed-loop cooling system wherein the fluid return line **88** returns the cooling fluid to the fluid pump **34** of the cooling fluid supply **33**. The cooling fluid supply **33** cools the returned cooling fluid from the fluid return line **88** before recirculating at least a portion of the returned cooling fluid through the microwave ablation system **10**.

In another embodiment, the fluid return line **88** connects to a suitable drain and/or reservoir (e.g., cooling fluid from the ablation probe **12** is not returned to the cooling fluid supply **33**). Cooling fluid reservoir **36** of the cooling fluid supply **33** provides a continuous supply of cooling fluid to the fluid pump **34**. Cooling fluid reservoir **36** may also include a temperature control system (not shown) configured to maintain the cooling fluid at a predetermined temperature. Coolant fluid may include any suitable liquid or gas, including air, or any combination of liquid and gas.

The ablation probe **12** may include any suitable microwave antenna **40** such as, for example, a dipole antenna, a monopole antenna and/or a helical antenna. The microwave generator **14** may be configured to provide any suitable electrical energy within an operational frequency from about 300 MHz to about 10 GHz. The physical length of the microwave antenna **40** is dependent on the frequency of the microwave energy signal generated by the microwave generator **14**. For example, in one embodiment, a microwave generator **14** providing a microwave energy signal at about 915 MHz drives an ablation probe **12** that includes a microwave antenna **40** with a physical length of about 1.6 cm to about 4.0 cm.

FIG. **2**A is an enlarged view of the distal portion of the ablation probe **12** of FIG. **1** and includes a feed line **20**, a proximal radiating portion **42** and a distal radiating portion **44**. The proximal radiating portion **42** and the distal radiating portion **44** form a dipole antenna **40**. As illustrated in FIG. **2**A, the proximal radiating portion **42** and the distal radiating portion **44** are unequal thereby forming an unbalanced dipole antenna **40**. The ablation probe **12** includes a sharp tip **48** having a tapered end **24** that terminates, in one embodiment, at a pointed tip **26** to allow for insertion into tissue with minimal resistance at a distal end of the radiating portion **18**. In another embodiment, the radiating portion **18** is inserted into a pre-existing opening or catheter and the tip may be rounded or flat.

The sharp tip **48** may be machined from various stock rods to obtain a desired shape. The sharp tip **48** may be attached to the distal radiating portion **44** using various adhesives or bonding agents, such as an epoxy sealant. If the sharp tip **48** is metal, the sharp tip **48** may be soldered to the distal radiating portion **44** and may radiate electrosurgical energy. In another embodiment, the sharp tip **48** and a distal radiating portion **44** may be machined as one piece. The sharp tip **48** may be formed from a variety of heat-resistant materials suitable for penetrating tissue, such as ceramic, metals (e.g., stainless steel) and various thermoplastic materials, such as polyetherimide or polyimide thermoplastic resins, an example of which is Ultem® sold by General Electric Co. of Fairfield, Conn.

FIG. **2**B is a longitudinal cross-sectional view of a section of the feed line **20** of the ablation probe **12** of FIG. **1**, and FIG. **2**C is a transverse, cross-sectional view of the feed line **20** of the ablation probe **12** of FIG. **2**B. Feed line **20** is coaxially formed with an inner conductor **50** at the radial center surrounded by a dielectric layer **52** and an outer conductor **56**.

The inflow hypotube **55** is spaced apart and disposed radially outward from the outer conductor **56**. The outer surface of the outer conductor **56***b* and the inner surface of the inflow hypotube **55***a* form an inflow channel **17***i* allowing cooling fluid to flow distally through the feed line **20** of the ablation probe **12** as indicated by the arrows within the inflow channel **17***i*. The inflow hypotube **55** may be formed from a variety of heat-resistant materials, such as ceramic, metals (e.g., stainless steel), various thermoplastic materials, such as polyetherimide or polyimide thermoplastic resins (e.g., Ultem®), or composite medical tubing, an example of which is PolyMed sold by Polygon of Walkerton, Ind. In one embodiment, the inflow hypotube **55** may have a wall thickness less than about 0.010 inches. In another embodiment, the inflow hypotube **55** may have a wall thickness less than about 0.001 inches.

The outer hypotube **57** is spaced apart from, and radially outward from, the inflow hypotube **55**. The outer surface of the inflow hypotube **55***b* and the inner surface of the outer hypotube **57***a* form an outflow channel **17***o* that allows cooling fluid to flow proximately through the feed line **20** of the ablation probe **12** as indicated by the arrows within the outflow channel **17***o*. The outer hypotube **57** may be formed from a variety of heat-resistant materials, such as ceramic, metals (e.g., stainless steel), various thermoplastic materials, such as polyetherimide, polyimide thermoplastic resins (e.g., Ultem®), or composite medical tubing (e.g., PolyMed). In one embodiment, the outer hypotube **57** may have a wall thickness less than about 0.010 inches. In another embodiment, the outer hypotube **57** may have a wall thickness less than about 0.001 inches.

The substantially radially concentric cross-sectional profile of the feed line, as illustrated in FIG. **2**C, provides uniform flow of fluid in both the inflow channel **17***i* and the outflow channel **17***o*. For example, an inflow channel gap G**1** defined between the outer surface of the outer conductor **56***b* and the inner surface of the inflow hypotube **55***a* is substantially uniform around the circumference of the outer conductor **56**. Similarly, an outflow channel gap G**2** defined between the outer surface of the inflow hypotube **55***b* and the inner surface of the outer hypotube **57** is substantially uniform around the circumference of the inflow hypotube **55**.

In addition, the cross-sectional area of the inflow channel **17***i* and the outflow channel **17***o* (i.e., the effective area of each channel in which fluid flows) is the difference between the area at the outer surface of the inflow channel **17***i* and the outflow channel **17***o* (i.e., the area at the inner diameter of the inflow hypotube **55** and the area at the inner diameter of the outer hypotube **57**, respectively) and the area at the inner surface of the inflow channel **17***i* and the outflow channel **17***o* (i.e., the area at the outer diameter of the outer conductor **56** and the area at the outer diameter of the inflow hypotube **55**). The cross-sectional area of the inflow channel **17***i* and the outflow channel **17***o* is substantially uniform along the longitudinal length of the feed line **20**. In addition, transverse shifting of the inflow hypotube **55** within the outer hypotube **57** or transverse shifting of the outer conductor **56** within the inflow hypotube **55**, may create a non-uniform inflow or outflow channel gap G**1**, G**2**, but will not affect the cross-sectional area of either the inflow channel **17***i* and/or the outflow channel **17***o*.

FIG. **2**D, which is a perspective view of the radiating portion **18** of FIG. **1**, illustrates the inflow fluid flow pathways. The radiating portion **18** is formed by inserting the distal portion of the feed line **20** into the microwave antenna **40**.

The feed line **20** is configured to provide cooling fluid and a microwave energy signal to the microwave antenna **40**. As discussed hereinabove, the feed line **20** provides cooling fluid through the inflow channel **17***i* formed between the inflow hypotube **55** and the outer conductor **56** of the feed line **20**. The feed line **20** also provides a microwave energy signal between the inner conductor **50** and the outer conductor **56**.

The antenna **40** includes a tapered inflow transition collar **53**, a channeled puck **46**, a distal radiating portion **44**, including a plurality of antenna sleeve stops **68***a*-**68***d*, and a sharp tip **48**. The feed line **20**, when inserted into the antenna **40**, connects the outer conductor **56** to the tapered inflow transition collar **53** and the inner conductor **50** to the distal radiating portion **44**.

When the radiating portion **18** is removed from tissue after energy, e.g., microwave energy, is applied to a tissue volume, a shield is placed between the radiating portion **18** and the patient and clinician. As shown in FIG. **3**, the shield may include a retractable sheath **302** that surrounds the entire length of the shaft **15** in a fully-extended state. The retractable sheath includes a retractable sheath **302** and a tip cover **304**. In some embodiments, the retractable sheath **302** is a compressible plastic cylinder. The tip cover **304** covers the pointed tip **26** to prevent injury. The tip cover **304** may be made of a semi-rigid or rigid material (e.g., a semi-rigid or rigid plastic). The retractable sheath **302** attaches to the handle **320**.

In some embodiments, the retractable sheath **302** and/or the tip cover **304** are made of a compressible, electrically conductive material formed in the shape of a cylinder. The compressible, electrically conductive material may be a metal, such as copper. In other embodiments, the retractable sheath **302** and/or the tip cover **304** are coated on their inner and/or outer surfaces with a compressible, electrically conductive material. The retractable sheath **302** and/or the tip cover **304** may be electrically coupled to electrical ground **315** to form an electromagnetic enclosure, which contains the electromagnetic fields generated by the radiating portion **18** to prevent radiation into the environment.

Because the retractable sheath **302** is compressible, the tip cover **304** is movable along a longitudinal axis **314** of the shaft **15**. As shown in FIG. **4**, when the shaft **15** is inserted in tissue **402**, the bottom surface **310** of the tip cover **304** mates with the outside surface **404** of a target volume of the tissue **402**, which pushes the tip cover **304** towards the handle **320** and compresses the retractable sheath **302**. When the shaft **15** is removed from tissue **402**, the tip cover **304** and the retractable sheath **302** decompress and extend to cover the entire length of the shaft **15**.

FIG. **5**A shows a retractable sheath **500** having fluid conduits **514**, **516**. A cooling fluid **524**, **526** having appropriate dielectric properties flows through the fluid conduits **514**, **516** to form a fluid shield around the radiating portion **18** of the shaft **15**. The fluid conduits **514**, **516** are formed between the inner surface of the outer wall **510** and the outer surface of the inner wall **512**. Multiple conduits may be formed in the retractable sheath **500** by forming conduit walls **513**, **515** that extend between the inner surface of the outer wall **510** and the outer surface of the inner wall **512**. The conduit wall **513** forms a first fluid conduit **514** and the conduit wall **515** forms a second fluid conduit **516**. In other embodiments, more than two conduit walls may be formed in the retractable sheath **500** to provide more than two fluid conduits.

The conduit walls **513**, **515** shown in FIGS. **5**A and **5**B have a linear shape along the length of the retractable sheath **500**. In other embodiments, however, the conduit walls **513**, **515** may have a non-linear shape, such as a curved shape.

As shown in FIG. **5**A, the fluid conduit **514** may carry a cooling fluid **524** to the distal end **521** of the retractable sheath **500** and the fluid conduit **516** may carry the cooling fluid **524** to the proximal end of the retractable sheath **500**. The retractable sheath **500** may include a tip cover (not shown) at the distal end **521** of the retractable sheath **500** that directs the cooling fluid **524** flowing in the fluid conduit **514** to the fluid conduit **516**. In this manner, the cooling fluid **524** may be circulated through the retractable sheath **500**.

As illustrated in FIG. **5**B, when the shaft **15** is placed within tissue, the retractable sheath **500** compresses to a retracted state. When the shaft **15** is removed from the tissue, the fluid pump **34** supplies a cooling fluid **524** to the retractable sheath **500** under a working pressure sufficient to extend the retractable sheath **500** to the extended state shown in FIG. **5**A.

In some embodiments, the metal-coated retractable sheath of FIGS. **3** and **4** is combined with the retractable sheath **500** of FIGS. **5**A and **5**B. For example, the retractable sheath **500** may be coated with a metal or any other electrically conductive material.

FIG. **6** shows a cross-sectional side view of an ablation probe **600**, e.g., a microwave ablation probe, having an expandable balloon **610**. The shaft **615** is a hollow elongated shaft or introducer having a wall **616** that encloses an electrical conductor having an antenna **618**, e.g., a microwave antenna, and a coaxial cable **620**. The coaxial cable **620** is electrically coupled to the antenna **618** and supplies energy, e.g., microwave energy, to the antenna **618**. The space between the inner surface of the wall **616** and the outer surfaces of the antenna **618** and the coaxial cable **620** forms a fluid conduit **622** through which cooling fluid flows to cool the antenna **618**.

The ablation probe **600** also includes multiple apertures **604** formed in the wall **616** of the shaft **615**. The apertures **604** are formed around the shaft **15** along the length of the antenna **618**. Alternatively, the apertures **604** are formed around the shaft **15** along a portion of the length of the antenna **618** or near the antenna **618**. The expandable balloon **610** is disposed on the outer surface of the wall **616** and is configured to cover the apertures **604**.

When the ablation probe **600** is placed in tissue and is transferring energy to the tissue, the balloon **610** maintains a normal state **626** in contact with or in close proximity to the outer surface of the wall **616**. When the ablation probe **600** is removed from the tissue, the fluid conduit **622** carries a shielding fluid **624**, which may be a pressurized fluid, to the apertures **604**. The shielding fluid **624** flows through the apertures **604** and expands the balloon **610** to an expanded state **628**. In the expanded state **628**, the balloon **610** defines and holds a volume **630** of shielding fluid **624** around the antenna **618**. The volume **630** of shielding fluid **624** absorbs and attenuates the energy radiating from the antenna **618** before the energy can radiate into the environment.

In some embodiments, the ablation probe **600** interfaces with the fluid pump **34** of FIG. **1** that is configured to supply a cooling fluid to the ablation probe **600** at a pressure level sufficient to maintain the balloon **610** in an expanded state **628** when the ablation probe **600** is outside of tissue. But, when the ablation probe **600** is inserted into tissue, the tissue compresses the balloon **610** against the outer surface of the shaft **615** to bring the balloon **610** back to its normal state **626**. When the ablation probe **600** is removed from tissue, the pressure of the cooling fluid expands the balloon **610** to an expanded state **628** and forms a large volume of fluid around the antenna **618** to absorb most of the electromagnetic energy radiating from the antenna **618**.

FIG. **7**A is a perspective view of an ablation probe **700** having a temperature indicator **702** (e.g., a passive temperature indicator) disposed on the outer surface of the handle **306**. The temperature indicator **702** may optionally be disposed on the outer surface of the shaft **15**. The temperature indicator **702** is a device that displays the temperature of the handle **306** or the shaft **15**. For example, the temperature indicator **702** may include a material that varies in color or brightness as the temperature of the handle **306** or the shaft **15** varies. In particular, the brightness of the material may increase as the temperature of the handle **306** or the shaft **15** increases.

FIG. **7**B illustrates an embodiment of the temperature indicator **702**. The temperature indicator **702** includes a layer of thermal gel **710**, e.g., a gel pad, disposed on the surface of the handle **308** and thermal paper **712** disposed on the layer of thermal gel **710**. The layer of thermal gel **710** may attach to the handle **308** (or the shaft **15**) through a thermally conductive adhesive.

As described above, the thermal paper **712** may change color to indicate a change in temperature of the handle **308** or shaft **15** to which the temperature indicator **702** is attached. Thus, when the ablation probe **700** is removed from tissue, any energy radiating from the antenna **618** heats the shaft **15** and the handle **308** through thermal conduction. The heat in the handle **308** then transfers through the layer of thermal gel **710** to the thermal paper **712** and changes the color of the thermal paper **712**. The changed color of the thermal paper **712** indicates to the clinician that the temperature of the handle **308** exceeds a predetermined level.

In some embodiments, the temperature indicator **702** is disposed on the handle **306** of an ablation probe that also includes the retractable sheath **302** of FIGS. **3** and **4**. In other embodiments, the temperature indicator **702** is disposed on the retractable sheath **302** of FIGS. **3** and **4** in case the retractable sheath **302** absorbs heat from the radiating portion **18** of the shaft **15** and heats up.

In some embodiments, the ablation probe **12** is reconfigured to feed a shielding fluid to the radiating portion **18** of the shaft **15** in order to reduce or eliminate radiation from the shaft **15** into the environment. As illustrated in FIG. **8**A, the ablation probe **12** includes a fluid circuit module **800** that is fluidly coupled to a shielding fluid source **801** via a second fluid supply conduit **811**. As described in greater detail below, the fluid circuit module **800** receives shielding fluid from the shielding fluid source **801** and supplies it to the radiating portion of the shaft **15** when the shaft **15** is removed from tissue after an ablation procedure is completed.

The fluid circuit module **800** includes a button **804** that allows a user of the ablation probe **12** to control the supply of shielding fluid to the radiating portion **18** of the shaft **15**. For example, the fluid circuit module **800** may be configured (1) to supply the cooling fluid to the radiating portion **18** of the shaft **15** when the user depresses the button **804** and (2) to supply a mixture of the cooling fluid and the shielding fluid to the radiating portion **18** of the shaft **15** when the user releases the button **804**. Alternatively, the fluid circuit module **800** may be configured (1) to supply the cooling fluid to the radiating portion **18** of the shaft **15** when the user depresses the button **804** a first time and (2) to supply a mixture of the cooling fluid and the shielding fluid to the radiating portion **18** of the shaft **15** when the user depresses the button **804** a second time.

FIGS. **8**B and **8**C are schematic diagrams of an embodiment of the fluid circuit module **800** of FIG. **8**A. FIGS. **8**B and **8**C illustrate the operation of an embodiment of the fluid circuit module **800** that allows a user to select whether to supply a cooling fluid or a mixture of the cooling fluid and a shielding fluid to the radiating portion **18** of the shaft **15** of the ablation probe **12**. As shown in FIG. **8**A, the fluid circuit **800** includes the fluid supply conduit **86** (hereinafter referred to as the first fluid supply conduit **86**) fluidly coupled between the fluid pump **34** of FIG. **1** and a common fluid supply conduit **810**. The common fluid supply conduit **810**, in turn, is in fluid communication with the shaft **15**.

The fluid circuit **800** also includes a bypass fluid conduit **822** that is fluidly coupled to the first fluid supply conduit **86** through a bypass fluid chamber **805**. The flow of fluid through the bypass fluid conduit **822** is controlled by a bypass valve assembly **808**. The bypass valve assembly **808** includes a piston **806** that is movable in a vertical direction within the bypass fluid chamber **805**. The bypass valve assembly **808** also includes a button **804** or other similar manual control mechanism coupled to the piston **806** that allows a user to move the piston **806** within the bypass fluid chamber **805**.

In operation, when a user depresses the button **804** to move the piston **806** to the bottom of the bypass fluid chamber **805**, a first fluid **840** supplied by the fluid pump **34** flows through the first fluid supply conduit **86**, the bypass fluid chamber **805**, and the common fluid supply conduit **810** to the shaft **15**. The first fluid **840**, however, does not enter the bypass fluid conduit **822** because the piston **806** covers the inlet of the bypass fluid conduit **822**. The common fluid supply conduit **810** supplies the first fluid **840** to the shaft to facilitate the radiation of microwave energy from the radiating portion of the conductor disposed within the shaft **15**. The fluid circuit **800** also includes a fluid return line **88** that carries the first fluid **840** returned from the shaft **15** to the fluid pump **34**.

As shown in FIG. **8**B, the fluid circuit **800** also includes the second fluid supply conduit **811**, which supplies a second fluid **842** (e.g., a shielding fluid or a cooling fluid) to the common fluid conduit **810**. The common fluid conduit **810** delivers the second fluid **842** to the shaft to minimize or prevent radiation of electromagnetic energy from the radiating portion of the shaft **15** to tissue or the surrounding environment. The second fluid **842** may be any fluid that absorbs the electromagnetic energy radiating from the antenna. For example, the second fluid **842** may be a liquid solution containing particles that absorb electromagnetic energy radiating from the antenna.

To pump the second fluid **842** through the second fluid supply conduit **811**, the fluid circuit **800** incorporates a second fluid pump assembly **825**. The second fluid pump assembly **825** includes a fluid pump **830** and an impeller **828** coupled to the fluid pump **830**. As shown in FIG. **8**B, the fluid pump **830** is positioned within the second fluid supply conduit **811**. The impeller **828** is operatively coupled to the fluid pump **830** through a shaft **829**. The impeller **828** is positioned within the bypass fluid conduit **822** so that the first fluid **840** flowing through the bypass fluid conduit **822** causes the impeller to rotate and drive the fluid pump **830**. In other embodiments, the second fluid pump assembly **825** may include different components that use the flow of the first fluid **840** flowing through the bypass fluid conduit **822** to cause the second fluid **842** to flow in the second fluid supply conduit **811**.

The second fluid supply conduit **811** also includes a check valve **832** that allows the second fluid to flow in one direction from a second fluid source (not shown) to the common fluid conduit **810**. The check valve also prevents any first fluid **840** flowing in the first fluid supply conduit **86** from entering the second fluid supply conduit **811**. In some embodiments, the check valve **832** is a duck bill valve.

When the user desires to apply microwave energy to tissue, the user depresses the button **804** with his/her finger to cause the first fluid **840** to flow through the common fluid supply conduit **810** to the radiating portion of the shaft **15**. As described above, the first fluid **840** increases the efficiency of the radiating portion of the microwave conductor disposed within the shaft **15**. When the user desires to stop applying microwave energy to tissue, the user removes his/her finger from the button **804** or depresses the button **804** a second time to cause the second fluid **842** to flow through the common fluid supply conduit **810** to the shaft **15** to shield the radiating portion of the microwave conductor. For example, the bypass valve assembly **808** may be spring loaded so that the bypass valve assembly **808** returns to the up position **809** when the user removes pressure from the button **804**.

In the up position **809**, the piston **806** prevents the first fluid **840** from flowing to the common fluid supply conduit **810** and directs the first fluid **840** into the bypass fluid conduit **822**. The first fluid **840** flows through the impeller **828** causing it to rotate and drive the fluid pump **830** through the shaft **829** of the fluid pump assembly **825**. Then, the fluid pump **830** pumps the second fluid **842** from a second fluid source (not shown) through the check valve **832** to the common fluid supply conduit **810**. The first fluid **840** flows out of the bypass fluid conduit **822** and into the fluid return conduit **820**, which carries the first fluid **840** to the fluid pump **34**. The second fluid **842** flows to the shaft **15** via the common fluid supply conduit **810** and then returns from the shaft **15** via the fluid return conduit **820**. The second fluid **842** mixes with the first fluid **840** and returns to the fluid pump **34**.

FIGS. **9**A and **9**B show another embodiment of a fluid circuit **900** that allows the user to select whether to supply a cooling fluid or a mixture of a cooling fluid and another fluid to the shaft **15**. Similar to the embodiment of FIGS. **8**B and **8**C, the fluid circuit **900** includes a first fluid supply conduit **86** and a second fluid supply conduit **904** that feed into a common fluid supply conduit **920**. Unlike the embodiment of FIGS. **8**B and **8**C, however, the first fluid supply conduit **86** includes a first recessed portion **910** and the second fluid supply conduit **811** includes a second recessed portion **914**. The first recessed portion **910** is shaped and dimensioned to receive an impeller **908** and the second recessed portion **914** is shaped and dimensioned to receive a fluid pump **912**. As in the embodiment FIGS. **8**B and **8**C, the impeller **908** and fluid pump **912** are operatively coupled to each other and form a portion of a fluid valve assembly **915**.

The fluid valve assembly **915** also includes a button **906** or other control mechanism that is coupled to the impeller **908**. The first fluid supply conduit **86** includes a first recessed portion **910** and the second fluid supply conduit **904** includes a second recessed portion **914**. The fluid valve assembly **915** can move between an up position and a down position **913** within the first and second recessed portions **910**, **914**. The fluid valve assembly **915** is spring loaded with a spring **916** that is positioned between the bottom surface of the second recessed portion **914** and the bottom surface of the second fluid pump **912** to maintain the fluid valve assembly **915** in the up position **911**. Other types and arrangements of springs could also be used to maintain the fluid valve assembly **915** in the up position **911**.

As shown in FIG. **9**A, if the button **906** is depressed, a first fluid **940** flows through the first fluid supply conduit **86** to the common fluid supply conduit **920**, while no fluid flows through the second fluid supply conduit **904**. This is because the impeller **908** is positioned in the first recessed portion **910** away from the flow of the first fluid **940** so that the first fluid **940** cannot cause the impeller **908** to rotate and drive the second fluid pump **912**. Also, the second fluid pump **912** is positioned in the second recessed portion **914** so that the second fluid pump **912** cannot draw the second fluid **942** through the second fluid supply conduit **904**.

As shown in FIG. **9**B, when the button **905** is released, the impeller **908** moves into the flow of the first fluid **940** and the second fluid pump **912** moves into the flow path of the second fluid **942**. The flow of the first fluid **940** causes the impeller **908** to rotate. The impeller **908**, in turn, drives the second fluid pump **912**. In operation, the second fluid pump **912** draws the second fluid **942** through the second fluid supply conduit **904** and into a mixing area **924** where the first fluid **940** flowing through the impeller **908** mixes with the second fluid **942** to form a third fluid **922**. The fluid valve assembly **915** may include gears that control the speed of the second fluid pump **912** and thus the flow rate of the second fluid **942** to control the ratio of first fluid **940** to second fluid **942** in the third fluid **922**. In this manner, the properties of the third fluid **922** may be adjusted to improve its ability to shield the radiating portion of the ablation probe from nearby tissue or the external environment.

In some embodiments, the first fluid **940** is a water-based buffer solution and the second fluid **942** is air or a similar gas, such as nitrogen, which agitates the water-based buffer solution when the button **905** is released. The air and buffer solution mixture may have different dielectric properties than the buffer solution alone. These different dielectric properties would hinder unnecessary energy transfer from the radiating portion of the shaft or probe into the environment.

The structures and methods described above for reducing or eliminating energy that radiates from ablation probes into the environment may be used in any combination to achieve varying levels of shielding. For example, an ablation system may incorporate the apertures **604** and the balloon **610** of FIG. **6**, and the fluid circuit module **800** of FIGS. **8**A-**8**C. In such an ablation system, the fluid circuit module **800** supplies shielding fluid to the balloon **610** through the apertures **604** when a user removes his/her finger from the button **804** at the completion of an ablation procedure. The shielding fluid is supplied to the balloon **610** at a pressure level sufficient to expand the balloon **610** when the ablation probe is removed from the tissue.

In another example, an ablation system may incorporate the retractable sheath **500** of FIGS. **5**A-**5**B (i.e., the retractable sheath having fluid conduits) and the fluid circuit **900** of FIGS. **9**A-**9**B. In such an ablation system, a mixture of shielding fluid and cooling fluid is supplied to the retractable sheath **500** when a user removes his/her finger from the button **804** at the completion of an ablation procedure. In yet another example, an ablation system may incorporate the temperature indicator **702** of FIGS. **7**A and **7**B and the fluid circuit **800** of FIGS. **8**A-**8**C.

While several embodiments of the disclosure have been shown in the drawings and/or discussed herein, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A method of operating an ablation probe, comprising:

supplying a first fluid to a radiating portion of the ablation probe when the radiating portion is inserted in tissue; and

supplying a second fluid to the radiating portion of the ablation probe when the radiating portion is removed from tissue to shield the radiating portion of the ablation probe from the surrounding surgical environment.

2. The method according to claim **1**, wherein supplying the second fluid occurs while supplying the first fluid to the radiating portion.

3. The method according to claim **1**, further comprising terminating the step of supplying a first fluid to the radiating portion at the onset of the step of supplying the second fluid.

4. The method according to claim **1**, wherein supplying the second fluid includes pumping the second fluid using a flow of the first fluid.

5. The method according to claim **1**, wherein supplying the first fluid includes moving a fluid valve assembly from a first position to a second position.

6. The method according to claim **5**, wherein supplying the second fluid includes moving the fluid valve assembly from the second position to the first position.

7. The method according to claim **1**, wherein the first fluid facilitates transmission of energy from the radiating portion to tissue.

8. The method according to claim **1**, wherein the second fluid prevents transmission of energy from the radiating portion to the surrounding environment.

9. The method according to claim **1**, further comprising removing the first fluid, a mixture of the first fluid and the second fluid, or the second fluid away from the radiating portion.

10. The method according to claim **1**, wherein the second fluid is a liquid solution containing particles that absorb electromagnetic energy.

11. The method according to claim **1**, wherein the second fluid is selected from the group consisting of air and a gas containing nitrogen.

12. The method according to claim **1**, wherein the first fluid, the second fluid, or a mixture of the first fluid and the second fluid flows through a plurality of apertures at a distal end of the ablation probe to cause a balloon enclosing the plurality of apertures to expand.

13. The method according to claim **1**, further comprising retracting a retractable sheath around at least the radiating portion of the ablation probe to prevent at least a portion of the energy from radiating outside of the retractable sheath.

14. The method according to claim **13**, further comprising supplying the second fluid through a conduit formed by the retractable sheath.

15. The method according to claim **14**, wherein the supplying of the second fluid causes the retractable sheath to extend.

16. The method according to claim **13**, wherein the retractable sheath is a compressible plastic cylinder and at least a portion of the compressible plastic cylinder is coated with an electrically conductive material.

17. The method according to claim **16**, wherein the compressible, electrically conductive material is a metal.

18. The method according to claim **17**, wherein the metal is copper.

19. The method according to claim **13**, wherein the retractable sheath is electrically coupled to an electrical ground.

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